NASA’s New Millennium Program, The Space Technology 8 (ST8) Mission

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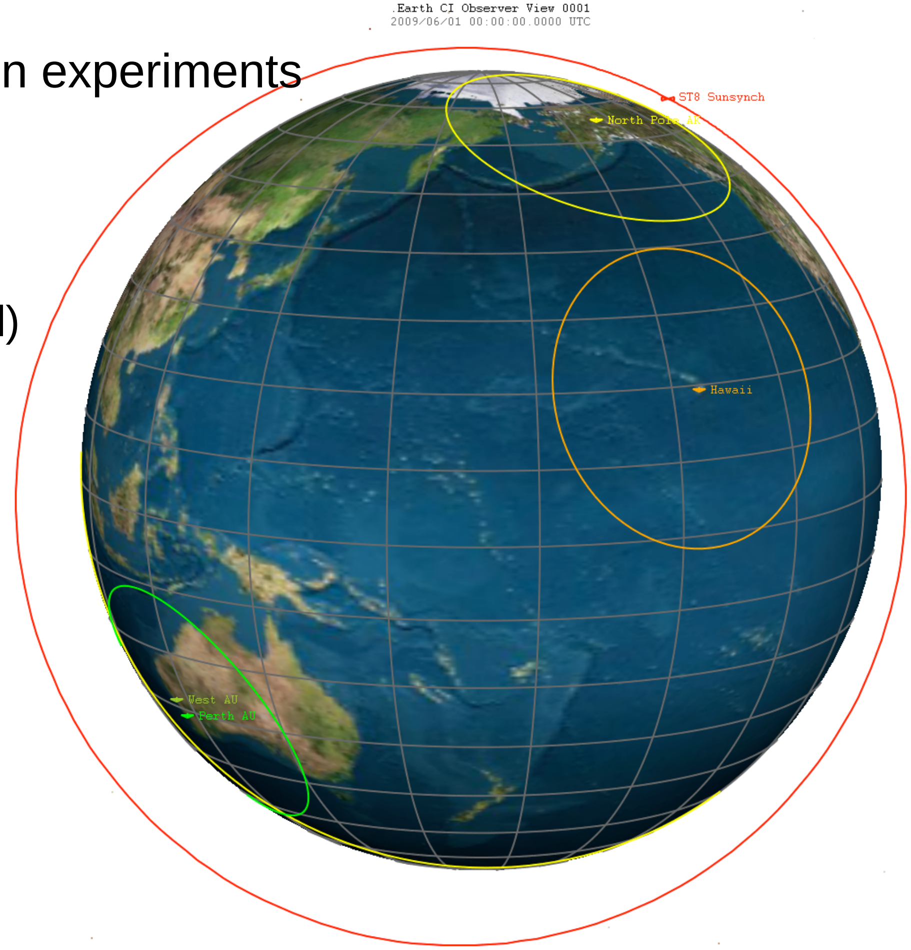
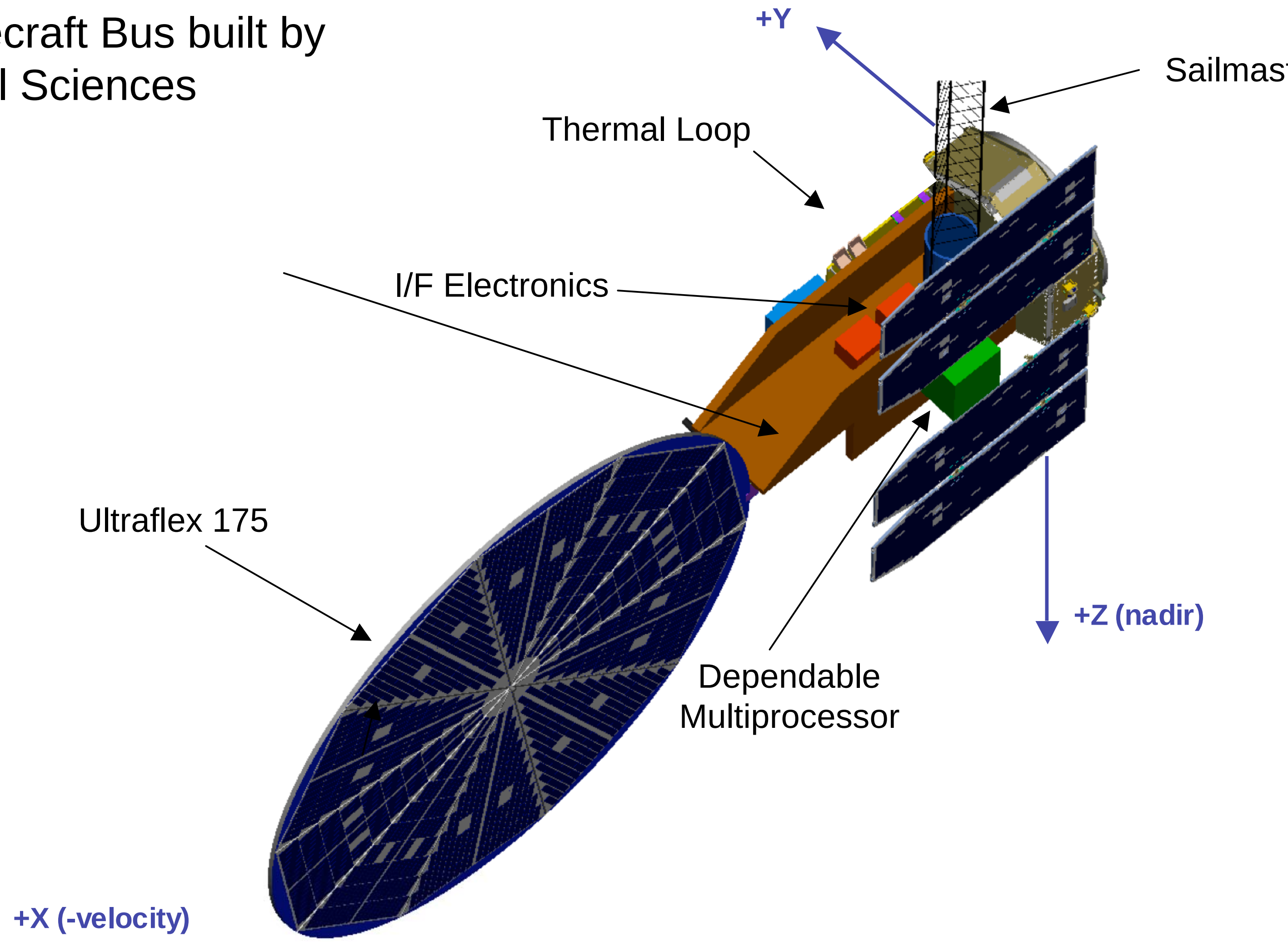
- Mission Overview
- Experiments:
  - SAILMAST (SM)
  - Ultraflex 175 (UF)
  - Thermal Loop (TL)
  - Dependable Multiprocessor (DM)
- Summary

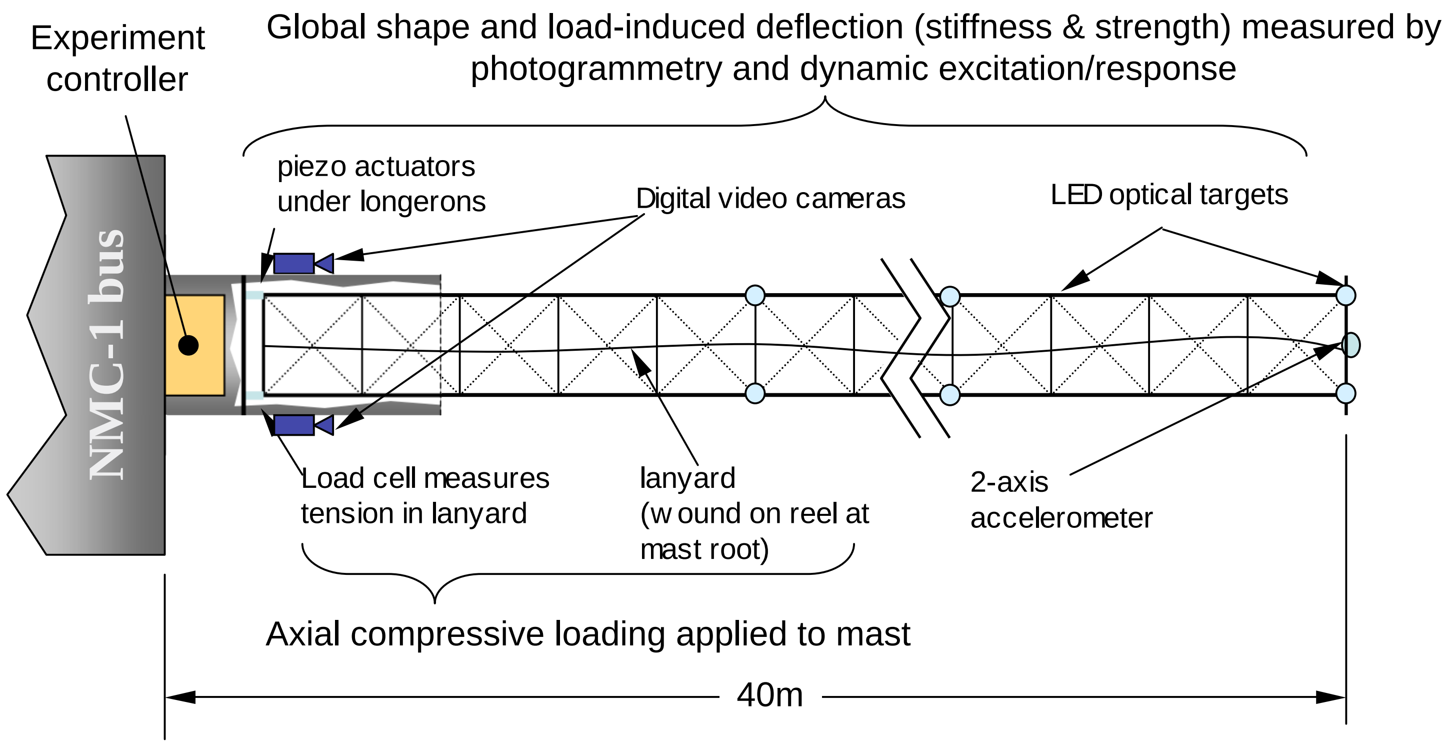
- ST8 carries 4 technology demonstration experiments
  - SAILMAST (ATK Space Systems)
  - Ultraflex 175 (ATK Space Systems)
  - Thermal Loop (GSFC)
  - Dependable Multiprocessor (Honeywell)
- Spacecraft bus (Orbital Sciences)
- Pegasus
- Launch in February 2009
- Low Elliptical (1300km X 320km), sun-synchronous orbit
- 7 month mission



Spacecraft Bus built by
Orbital Sciences



- **Flight experiment success is predicated on accurate:**
  - **Mast global shape measurements via photogrammetry**
  - **Axial load applied by deployment lanyard, measured by load cell**
  - **Dynamic response as measured by accelerometers on mast tip**

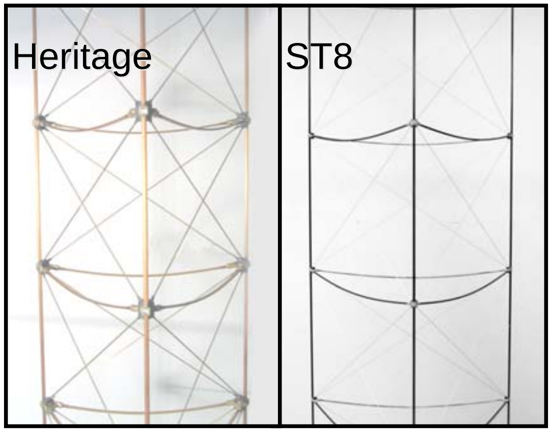


A flight validation of a new generation of gossamer booms will:

- Validate new modeling of behavior unique to extremely slender structures
- Validate the deployment and operation of a gossamer boom in the space environment

Compared to heritage boom designs, the SAILMAST is:

- Nearly double the slenderness
- Less than 1/3 the linear mass
- Too soft to enable measurement of its free state shape when offloaded in 1-G
  - 1-G behavior easily overwhelms the effects being modeled, making model correlation impossible



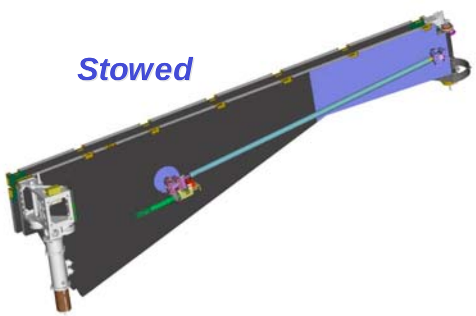
Heritage	ST8
$Ø_M$ = 25.5 cm	$Ø_M$ = 24.0 cm
L_S/L_D = 2.0%	L_S/L_D = 0.88%
r_L = 240 g/m	r_L = 31 g/m

- UltraFlex is an accordion fanfold flexible-blanket solar array comprised of interconnected triangular shaped ultra-lightweight substrates (gores)
- During deployment each interconnected gore unfolds and becomes tensioned to form a shallow umbrella-shaped membrane structure

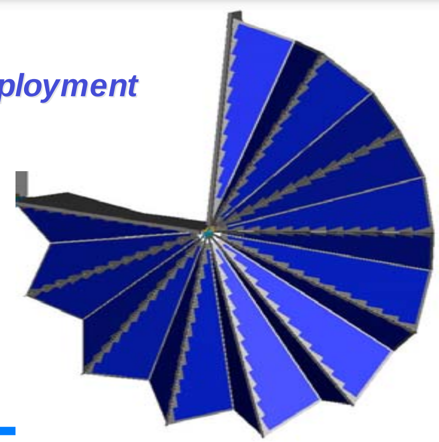
UltraFlex-175 technology advance provides extraordinary solar array performance

Ultra-lightweight (>175 W/kg), compact stowage volume (>40 kW/m³), and high deployed frequency

Stowed



Deployment



Deployed

Patent# 5,296,044

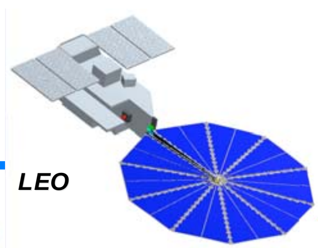
H. Abakians

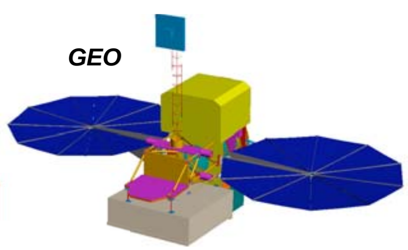
Performance Parameter	*7 kW UltraFlex-175*	*State-of-Art Rigid Array*
BOL Specific Power	**175-220 W/kg (depending on PV / circuit technology)**	60-70 W/kg
Stowed Packaging Efficiency	**> 40 kW/m ^{3}**	7-10 kW/m ^{3}
Deployed First Mode Frequency	**> 0.2 Hz**	0.1 Hz
Operational Limitations	**None**	None
Reliability	**High**	High
Normalized Cost	**Low (post-technology development)**	Low

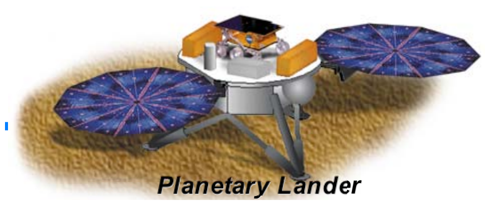
- **Ideal for mass and stowage volume-critical applications**

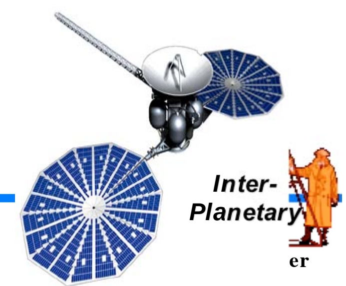
UltraFlex-175 is easily interchangeable with rigid array technology

Applications:

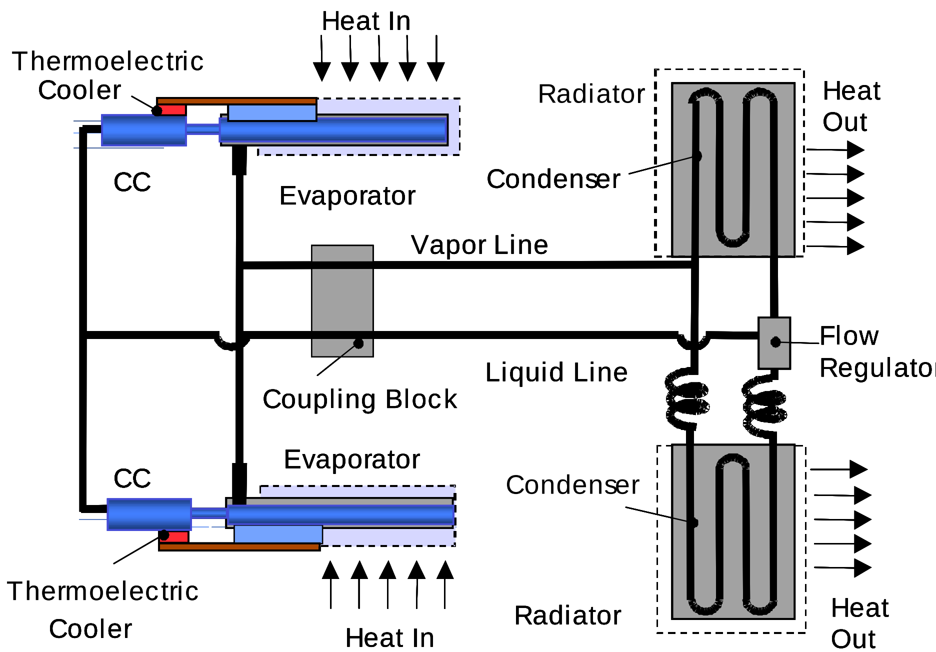








- Loop heat pipe containing two parallel evaporators and two parallel condensers
  - Passive and self regulating
  - Heat load sharing between evaporators
- Thermal Electric Coolers (TECs)
  - Maintain Condensation Chamber (CC) saturation temperature by providing heating and cooling
  - Assure reliable start-up and shutdown
  - Variable set point control for operation over a wide range of temperatures
- Coupling Blocks
  - Reduces control heater power requirements by transferring heat from vapor to return liquid
- Working Fluid
  - Anhydrous ammonia



Technology Benefits

State-of-the-Art	*ST8 Technical Advance*
LHP has a single evaporator	**LHP has multiple evaporators** **(ST8 will demonstrate an LHP with two evaporators)**
Requires supplemental heaters to maintain temperatures of off-instruments	**Heat load sharing among evaporators eliminates or reduces supplemental heater powers**
LHP has 25mm O.D. wick	**LHP has 8mm O.D. wick - reduced volume and mass**
Top-level transient model for LHPs with a single evaporator **No scaling rule has been established**	**Detailed transient model for LHPs with multiple evaporators** **Scaling rules will be established**
Relies on starter heater on evaporator for start-up **Power required: 20W to 40W**	**Uses TECs on CCs to ensure successful start-up** **Power required: less than 10W**
Control heater on CC for temperature control - cold biased, heating only, no cooling, **Heater power: 5W to 20W**	**TECs on CCs and coupling block on transport lines for temperature control - heating and cooling** **Heater power: 0.5W to 5W**

A COTS-Based spacecraft onboard processing system:

- Fully programmable, High throughput, Low power, Scalable
- Original system software for effective radiation upset immunity

An architecture and methodology that enables COTS based, high performance, scalable, multi-computer systems, incorporating co-processors, and supporting parallel/distributed processing for science codes, that accommodates future COTS parts/standards through upgrades.

An application software development and runtime environment that is familiar to science application developers, and facilitates porting of applications from the laboratory to the spacecraft payload data processor.

An autonomous controller for fault tolerance configuration, responsive to environment, application criticality and system mode, that maintains required dependability and availability while optimizing resource utilization and system efficiency.

Methods and tools which allow the prediction of the system's behavior across various space environments, including: predictions of availability, dependability, fault rates/types, and system level performance.

'Fly COTS Multiprocessors in Space'

Problems:

- **Single Event Upset (SEU) Problem: Space radiation induces transient faults in COTS hardware causing erratic performance and confusing COTS software**
- **Cooling Problem: Air flow is generally used to cool COTS multiprocessors, but there is no air in Space**
- **Power Efficiency Problem: COTS only employs power efficiency for compact Mobile Computing, not for scalable Multiprocessing Systems, but in Space power is severely constrained – even for Multiprocessing**

The DM's Problem - Solution

'Fly COTS Multiprocessors in Space'

– Solutions:

– **Single Event Upset (SEU) Problem: Space radiation induces transient faults in COTS HW causing erratic performance, confusing COTS SW**

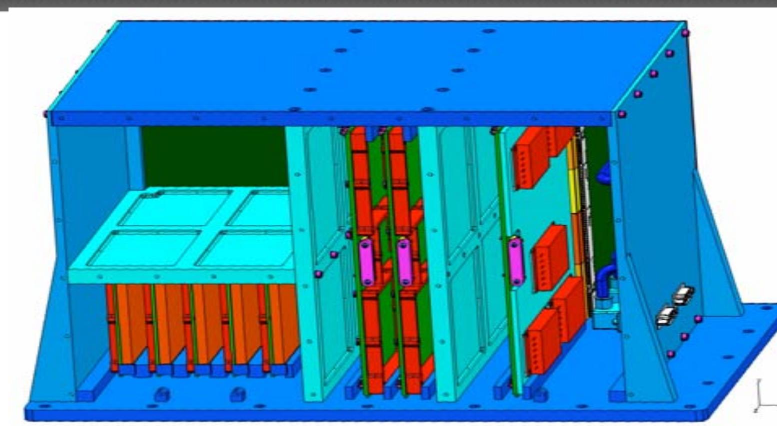
Solution – aggregate:

- Revise/Embellish COTS Sys SW for more agile transient fault recoveries
- Revise/Embellish COTS Sys SW to activate transient fault detects & responses
- Create Applications Services (API's) which facilitate shared detection and response between App's & Sys SW for accurate, low OH fault transient handling
- Replace SEU/Latch-up prone, non-throughput impacting COTS parts with less prone parts
- Model SEU transient fault effects for predictable multiprocessor performance

- **Cooling Problem: No air in Space**
  - Mine niche COTS aircraft/industrial conductive-cooled market, or upgrade convective COTS boards with heat-sink overlays and edge-wedge tie-ins

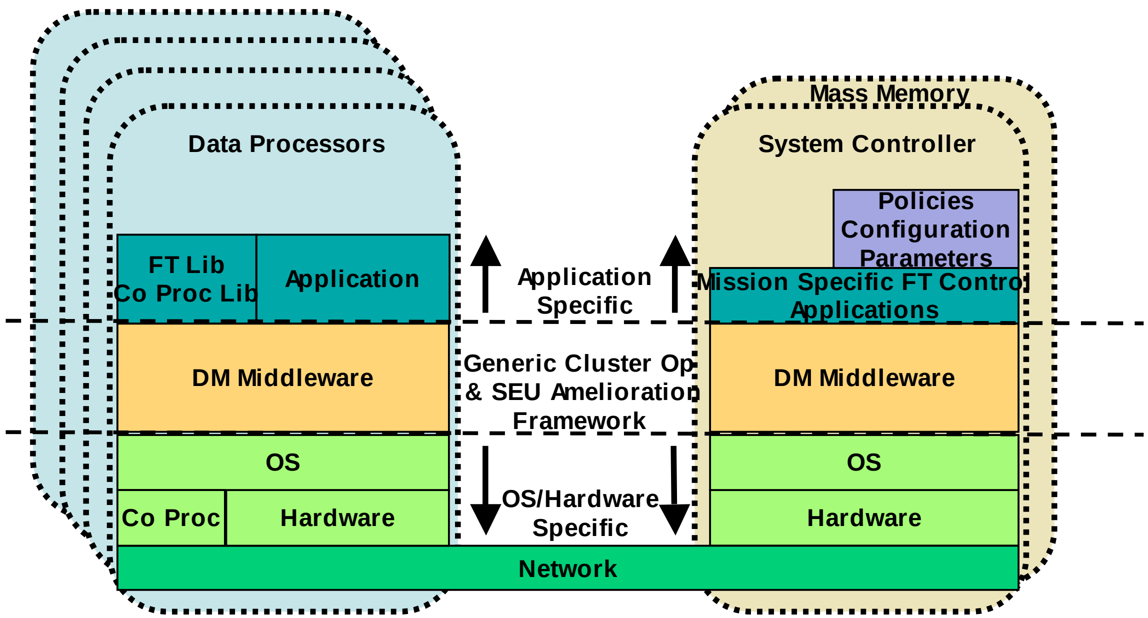
- **Power Efficiency Problem: COTS Multiprocessors are Power hogs**
  - Hybridize by mating COTS Multiprocessing SW with Mobile-Mkt COTS HW components

DM Flight Experiment Unit



Hardware View

- Dimensions
  10.6 x 12.2 x 18.0 in.
- Weight
  < 66.13 Lbs
- Power
  < 144W



Software View

- Multi-layered Sys SW
  - OS, Middleware, APIs
- SEU Immunity
  - Detection
  - Transparent Recovery
- Multi-processing
  - Combinable Modes
  - Parallel, Redundant

Summary

- Low-cost mission.
- Demonstrates 4 technology experiments which will enable future missions.
- Spacecraft based on existing Orbital Sciences product